Tsunami risk modelling for Australia: understanding the impact of data

Risk and Impact Analysis Group
Geoscience Australia

About Geoscience Australia

Within the portfolio of Resources, Energy and Tourism, Geoscience Australia plays a critical role by producing first-class geoscientific information and knowledge to enable the government and the community to make informed decisions about the exploration of resources, the management of the environment, the safety of critical infrastructure and the resultant wellbeing of all Australians.

The Risk & Impact Analysis Group's (RIAG) key role is to develop knowledge of the risk from natural and human-caused hazards for input to policy and operational decision makers for the mitigation of risk to Australian communities. RIAG achieves this through the development of computational methods, models and decision support tools for use in assessing the impact and risk posed by hazards. RIAG contributes to the National Research Priority of Safeguarding Australia by providing an improved understanding of the vulnerability of the built environment in Australia, including critical infrastructure. RIAG is also addressing the National Research Priority for an Environmentally Sustainable Australia through new work in the assessment of coastal vulnerability to climate change.

Project Background

The 2004 Indian Ocean Tsunami raised the importance of tsunami as a significant emergency management issue in Australia. The Australian government responded by initiating a range of measures to help safeguard Australia from tsunami, in particular the Australian Tsunami Warning System (ATWS). In addition to the ATWS the Australian Government is supporting some fundamental research into understanding the risk to Australian communities from tsunami.

Geoscience Australia, with the support from Emergency Management Australia, is developing a national tsunami hazard map based on earthquakes generated from the subduction zones surrounding Australia. These preliminary studies have highlighted sections of the Australian coastline which appear vulnerable to events of this type. More detailed studies are underway to develop a probabilistic understanding of these events so that a national tsunami hazard map may be produced. The associated risk is determined by the likelihood of the event and the resultant impact.

Modelling the impacts from tsunami events is a complex task. A simplification is obtained by taking a hybrid approach where two different models are combined: relatively simple and fast models are used for simulating the tsunami event and the wave propagation through open water. The impact from tsunami inundation is simulated with another type of model which is suitable for resolving the details of the run-up process and the resulting inundation, [1]. The inundation modelling is conducted using the ANUGA model which is a result of collaboration between the ANU and GA, [2]. It solves the 2D nonlinear shallow water wave equations using a finite volume method.

Project Aim

One of the critical requirements for reliable inundation modelling is an accurate model of the earth's surface that extends from the open ocean through the inter-tidal zone into the onshore areas to be studied. Production of a sufficiently accurate elevation model is a complex and difficult process made more difficult because the available elevation data inevitably will come from a number of different sources and will have a range of vintages, resolutions and reliability.

The State agencies responsible for managing tsunami risk are required to provide their elevation data for tsunami modelling which is crucial to understanding and managing the risk from tsunami. However, two related questions invariably arise when data is requested:

1. **What horizontal resolution is adequate for reliable modelling?**
2. **How do errors in the vertical elevation values affect model results?**

The first question deals with the true variability of the topography. Obviously, a flat surface needn't be sampled nearly as finely as a highly convoluted surface. The Nyquist sampling theorem is probably applicable here, but the 'true' shape is rarely known a-priori. Moreover, the wavelength, depth and scale of the problem all play important roles for this question. Is it possible to derive a generalisation or heuristic that, given an elevation dataset and a tsunami scenario, provides a measure of how reliable the model results will be?

The second question relates to sensitivity; how are error bars derived for the impact results if the error bars on each elevation point is known? ANUGA solves the 2D nonlinear shallow water wave equations using a finite volume method and typical models can take days of computational time so proper sensitivity analyses are often prohibitively expensive in terms of computational resources. Simply treating every elevation point as an independent variable and carrying out simulations for a vast range of realisations of the seafloor leads to extremely computationally intensive studies mainly due to the 'curse of dimensionality'. On the other hand, vertical error bars on the elevation data are probably not independent, so it might still be possible to derive an estimate of reliability of our model results if the uncertainty in elevation data is known.

The overarching aim of this project is thus to understand the uncertainties of the inundation model output based on the available input data. Data acquisition is expensive and State agencies will use the best available data. To date, Geoscience Australia has used this kind of data to develop inundation maps which are used by State emergency managers to develop evacuation plans. Currently, we have no understanding of the error in the maps.

The project will also assist State agencies if they wish to fill data gaps or reacquire data at better resolution and accuracy. Practicalities in terms of data capture methods and cost which limits the available resolution and accuracy have made it impractical to set any hard and fast rules for what is required.

Therefore, Geoscience Australia's desired outcomes are

1. Develop an understanding of the sensitivities of the inundation model to the horizontal resolution of elevation data. In particular,
    a. What is the relationship between the input wave in terms of amplitude, period, momentum and depth; and "wave number" or "variability" of the elevation data through which the wave is propagating?
    b. What sampling guidelines apply to the elevation data given a particular input wave and scale of the study area?
    c. Given a known elevation data set and a particular scenario, what can be said about the reliability of the model results? In other words: what is the required spatial resolution to model a tsunami wave "well enough"?
2. Develop an understanding of the sensitivities of the inundation model to the vertical uncertainty in the elevation data. In particular,
    a. With a given input wave and data set, what errors exist in the modelled wave?
    b. What is the relationship between the input wave (in terms of period or energy) and vertical accuracy of the input data?

c. What is the required vertical accuracy in the elevation data to model a tsunami wave "well enough"?
d. What can be said about how high-precision but low-accuracy data could affect or bias the results?
e. How is the accuracy of the modelled wave dependant on the complexity of the elevation data? That is, what degree of amplification and/or focusing occurs as a result of the accuracy of the elevation data?

where the inundation model is based on the 2D nonlinear shallow water wave equations.

Once the uncertainties in the data are characterised, and the sensitivity of the model is known (estimated), the next step might be to develop wave inundation/amplification classes whereby similar geometries can by treated as a class where factors such as roughness, slope, degree of focussing, etc are captured.

The final outcome would then be to

3. Develop an understanding of how the following two uncertainties affect the modelled inundation results:
    a. that which is associated with the uncertainty in the accuracy of the data at any one location, and
    b. that which is associated with the generalisation of a set of similar sites to an inundation class.

References

1. http://www.ga.gov.au/ausgeonews/ausgeonews200609/modelling.jsp
2. Nielsen O, Roberts S, Gray D, McPherson A & Hitchman A. 2005. Hydrodynamic modelling of coastal inundation. MODSIM 2005 International Congress on Modelling and Simulation, Modelling and Simulation Society of Australian and New Zealand, 518–523. www.mssanz.org.au/modsim05/papers/nielsen.pdf